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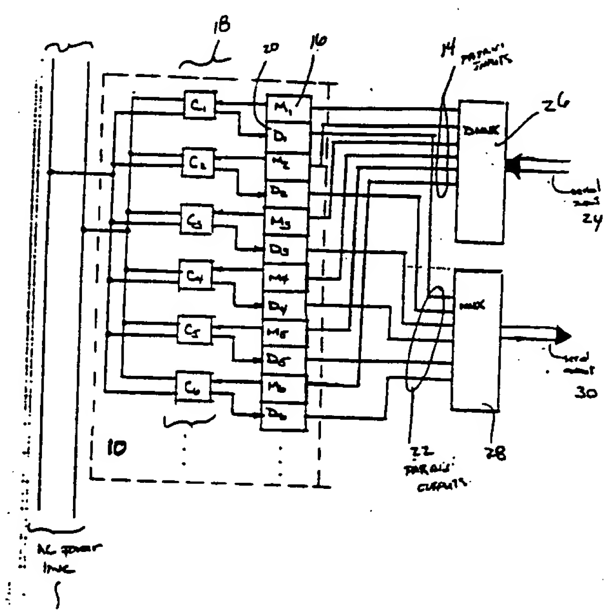
(54) Title: POWER LINE COUPLER MODEM DEVICE FOR COMMUNICATION OVER ELECTRICAL LINES

(57) Abstract

The present invention discloses an improved electrical communication apparatus which communicates high speed data/information over existing AC wiring (12), provides a phase linear environment for electrical transmission and reception of information on electrical wiring (12) and provides a means for simultaneous transmission and reception of multiple data/information streams (14, 22) via the use of dielectric core couplers (18). This invention provides a means for linking 2 or more microprocessor based or electronic devices via conventional electric lines such as power lines, building wiring, twisted pair, coaxial cable or other wiring.



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POWER LINE COUPLER MODEM DEVICE FOR COMMUNICATION OVER ELECTRICAL LINES

Field of the Invention

The present invention relates to communication apparatus used to send and receive high speed data over electrical lines. More specifically, it provides a means for high speed data to be sent and received over conventional electrical wiring or other electrical lines already existing in a building or over preexisting power lines between buildings and structures.

Description of the Prior Art

Presently, there are a number of devices that allow different types of information to be sent over electrical lines. For example, there are intercom, stereo, switch control, and line carrier modem systems which readily plug into an electrical outlet and allow transfer of information over conventional wiring to any other outlet in the same building.

The term conventional wiring includes wiring found in buildings, homes or other structures. Conventional wiring can be AC power lines, electrical wiring, coaxial, twisted pair, telephone, antenna, multibase or any other wiring that can carry electricity.

Intercom systems transfer a frequency modulated voice signal over an electrical AC line which is received at another point or socket on the electrical line and is demodulated back into its voice components. Switch control systems consist of a main switch control station plugged into an electrical outlet as well

as multiple receiving stations plugged into other electrical outlets. Each of the receiving stations may have a lamp or other appliance plugged into it. The main switch control station allows the user to press a selected button which switches a selected appliance on or off at a receiving station. The information sent from the switch control station to the receiving station is generally a frequency modulated on top of the AC voltage already present in the conventional electrical wiring. The frequency is received by the individual receiving stations. Each receiving station listens for a particular frequency which indicates whether to switch to the off or on position. Here only the simplest of information is sent over the conventional wiring.

There are also line carrier modems. A line carrier modem, such as one described in, Keith Nichols, "Build a Pair of Line-Carrier Modems," Radio Electronics, 87-91, (July 1988), is connected to a computer or personal computer and then plugged into an electrical outlet. Somewhere else on the same electrical line another computer is connected to one of the line carrier modems and also plugged into an electrical outlet. Data can be communicated from one computer to another via the line carrier modems. Generally, such modems, take a single data stream from the computer, modulate the data stream, then place it on top of the AC voltage present in the conventional wall wiring. This signal is then received by a second line carrier modem and demodulated back into the original data stream so that the second computer can receive the data from the first computer.

Existing line carrier modems are limited to a baud rate of 19.2 kbaud or less. This limitation is mainly due to the use of magnetic or iron core transformers in their design. These iron core transformers are used to couple the modulated data stream from the line carrier modem onto and off of the conventional wiring. These magnetic core couplers are not impedance matched to the electrical line characteristic impedance, and thus distort the modulated signal. This distortion limits the transmission and reception baud rate to 19.2 kbaud. Spread spectrum techniques are used in existing line carrier modems due to the problem encountered with standing waves. A standing wave occurs due to the mismatched impedance of the magnetic core couplers and the electrical line which causes a reactive coupling at carrier frequency. The standing wave will cause null points on the conventional wiring; the effect of which will cancel the transmission at the null point. Existing transmission or receiving line carrier modems, with their iron core or magnetic core transformers, are inept at filtering out a majority of the 60Hz harmonics from a 60Hz 120 volt electrical line. Iron core or magnetic core transformers/couplers are also phase non-linear, thus modulated signals sent along conventional wiring are of a different phase when received then as when transmitted. This unpredictable phase shift, associated with the coupling of the modulated signal to the electrical line, severely limits the use of encoding digital data with phase shift keying techniques.

At present, local area networks (LANs) and networking systems, such as Ethernet, are the industry choice for connecting multiple computer stations together. These networks generally consist of multiple computer stations, a network server, and a hard wired bus and/or electrical lines connecting every computer system. Each computer or station on the system has an address known by all the other computers or stations. For a first station to communicate with a second station it merely sends the address of the second station on the bus followed by pertinent data information. The information is received by a second station with the proper address. The second station may transmit data back to the first station using the same process.

LAN or Ethernet systems are expensive to install. One reason for the expense is the purchasing and installation costs of wiring an office complex. Wiring often must be installed underneath the floors or through the walls in order to meet building codes. At a later date, the installation of more wiring may be required to expand the system.

Local area networks and Ethernets transmit data over their communication lines at an extremely high rate of speed. This rate of speed can be up to and greater than 10 Mbaud on coaxial line and about 1 Mbaud over multiple twisted pair. At present, there is no available system that allows LAN or Ethernet expansion without hard wiring additional cabling throughout an office building. As mentioned earlier, existing line carrier modems can only transmit and receive data at about 19.2 kbaud.

They are not useful for expanding Ethernet or LAN systems because linking a pre-existing LAN System to presently existing line carrier modems for expansion purposes will slow the entire network down or make the system inoperable.

SUMMARY OF THE INVENTION

The invention includes communication apparatus which transmits and receives multiple modulated signals over an electrical line having a first station capable of receiving high speed data and converting the high speed data into multiple modulated signals for sending simultaneously over the electrical line to said second station. The second station is capable of simultaneously demodulating the multiple modulated signals and converting the signals back into high speed data; and each of the stations incorporates dielectric core couplers for coupling the multiple modulated signals between the electrical line and each station.

In light of all the foregoing, it is a primary object of the present invention to transmit and receive data at baud rates greatly exceeding 19.2 kbaud over preexisting conventional wiring.

It is a further object of the present invention to transmit and receive data over conventional wiring in a phase linear fashion such that phase shift keying techniques can be used in sending and receiving digital data.

It is another object of the present invention to resistively match a Power Line Coupler Modem to the electrical wiring characteristic impedance at the transmission frequency in order to eliminate standing waves. The elimination of standing waves will allow the Power Line Coupler Modem to transmit and receive without using spread spectrum modulation/demodulation techniques.

It is another object of the present invention to send and receive multiple modulated signals at the same time over conventional wiring.

It is yet another object of the present invention to provide an inexpensive means for installing and expanding LAN or networking systems such as Ethernet or Token Ring, etc.

It is an additional object of the present invention to allow multiple computers or stations to communicate via pre-existing electrical lines found within a building.

It is a further object of the present invention to allow computer systems to communicate via pre-existing power lines between buildings such that work stations or computer systems in one building can communicate with multiple work stations and/or computer systems in other buildings.

It is another object of the present invention to transmit and receive clear audio or video analog signals via conventional wiring in a phase linear manner.

DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram of basic Power Line Carrier Modem (PLCM) of the present invention.

Figure 2 is a block diagram of the PLCM organized to handle serial inputs and outputs.

Figure 3 is a block diagram of the PLCM incorporating quadrature phase shift keying in the modulation and demodulation stage.

Figure 4 is a block diagram of the PLCM incorporating quadrature phase shift keying and capable of handling high speed serial inputs and outputs.

Figure 5 is a block diagram of the PLCM configured to operate within a Local Area Network (LAN) system.

Figure 6 is a block diagram of the PLCM configured to operate within an Ethernet.

Figure 7 depicts numerous computers, printers and various devices interconnected via the PLCM.

Figure 8 depicts the coupling transformer of a power line coupler of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention, a Power Line Coupler Modem (PLCM), provides a means for high speed data communication over conventional wiring. The invention modulates multiple signals at different preselected modulation frequencies, then combines and sends the multiple modulated signals over conventional wiring. The multiple modulated signals are then received, separated and individually demodulated. Power Line Couplers, described in my pending patent application Serial No. 822,326, are used in the present invention to place and retrieve the multiple modulated signals onto and off of the conventional wiring. These couplers are phase linear at and close to their preselected frequencies and are capable of removing a majority of the AC harmonics associated with power line frequencies (60Hz) found on conventional wiring. Furthermore, operation of the PLCM can reach speeds in excess of 1 MBaud (with four to ten couplers) for 3 KM distances. It is emphasized that the transmission is in a parallel form rather than a serial form.

Figure 1 depicts a basic Power Line Coupler Modem (PLCM) 10 which consists of at least two Power Line Couplers (C_1 - C_n) 18 plus an equal number of modulators (M_1 - M_n) 16 and demodulators (D_1 - D_n) 20. Data, usually in the form of a digital bit stream, comes from a device capable of sending parallel digital data (not shown), such as a personal computer or microprocessor based device. It should be noted that the data could be analog information such as voice, video, stereo, or other analog signals.

Data enters the PLCM 10 via the parallel inputs 14. The data is modulated to a preselected modulation frequency by its associated modulator (M_1 - M_n) 16. After each data stream is modulated at the modulators it is passed to its associated coupler (C_1 - C_n) or Power Line Carrier (PLC) 18. Each coupler 18 is phase linear and resistively matched at or around the modulation (carrier) frequency to the characteristic impedance of the AC power line 12 to which it is connected. Each coupler (C_1 - C_n) 18 is connected to one another resulting in an addition of all the modulated data streams as they are connected to the conventional wiring or AC power line 12.

A second PLCM, shown in Figure 1, is identical to the first PLCM 10. The addition of all the modulated data streams enters the second PLCM 10 from the AC power line 12. The couplers of Figure 8 (C_1 - C_n) 18 are impedance matched to the AC power line 12 and phase linear at the preselected filter frequencies. Each coupler filters the incoming signal and extracts a single preselected modulated data stream. The modulated data stream is sent from the couplers (C_1 - C_n) 18 to an associated demodulator (D_1 - D_n) 16. Each demodulator 16 removes the modulating carrier signal from the data leaving the data which was sent by the first PLCM. This data is placed onto its associated parallel output lines. The output lines carry the data to an electronic device capable of receiving parallel digital data such as a computer, printer, or other electronic device.

This entire communication process can be repeated in the opposite direction. That is, the second PLCM can send data to the first PLCM via the AC power line 12. The generic data rate at which the parallel input 14 and output 22 lines are capable of operating at is in the range of 50 to 100 KSymbols/sec for each line. The PLCM can be configured to handle any size parallel bus and the signals on the bus can be anything from DC voltage levels to binary signals to multiple analog signals.

The maximum communication distance is calculated from the raw speed of each digital bit stream. Dividing the speed of an electron, 300,000 km/sec, by the speed of the bit stream, 100 KSymbols/sec, we get 3 km/bit. Normally only a fraction of the 300,000 km/sec can be assumed for electron speed, thus the maximum communication distance will be closer to 2 km.

Figure 2 depicts the basic PLCM 10 wherein the parallel inputs 14 are connected to a demultiplexer 26 and the parallel outputs are connected to a multiplexer 28. In this configuration the PLCM 10 can receive serial or parallel (herein "data stream) data stream on the input line 24 from a device capable of sending a data stream (not shown). The demultiplexer 26 receives the data stream and converts it to parallel data for the parallel input lines. The PLCM then operates as described above. In short, each signal on the parallel input line is modulated, then coupled to the AC power line. The signal is then received by a second PLCM wherein the modulated signals are coupled to the

PLCM, separated, filtered, demodulated and sent out on the parallel output lines 22.

The parallel output lines 22 are connected to a multiplexer which converts the parallel data back to its original data stream. This data stream can be received by an electronic device designed to receive serial or parallel data.

For example, referring to Figure 7, PC1, a personal computer, may have a data stream port through which it sends and receives data. PC1 may send data to PC2 through the AC power line by first sending the data stream to a first PLCM which connects the data in a modulated format onto the AC power line. A second PLCM then can receive the modulated data, change it back into its original data stream form and connect it PC2 which, in turn, receives the data. Each transmission is addressable to preselect the destination.

Since the basic PLCM configuration is capable of handling a symbol rate of 80 KSymbols/sec per each input or output parallel line, the addition of another parallel line acts as a data speed multiplier increasing the baud rate and overall throughput of the PLCM. For example, if two modulators and demodulators are used in each PLCM the overall throughput of the PLCM is 80 KSymbols/sec X 2 = 160 KSymbols/sec. If eight modulators and demodulators are used in the PLCM the overall throughput of the PLCM is 80 KSymbols/sec parallel line X 4 parallel lines = 320 Kbaud.

Quadrature phase shift keying modulation techniques are illustrated in Figure 3. As explained herein, quadrature phase shifting can be used successfully in the novel PLCM to double the baud rate of each input or output parallel line in the PLCM.

Figure 3 depicts a phase shifting PLCM 10a with parallel input lines 14 which carry digital data into the quadrature phase shift keying (QPSK) modulator 34. The QPSK modulator assigns a 90, 180, 270 or 360 degree phase shift for each two bits of data and shifts the modulation frequency accordingly. For example, data bits "00" are assigned a 90 degree phase shift, "01" are assigned 180, "10" are assigned 270 degrees and "11" assigned a 360 degree shift. This technique essentially packs the data in a 2:1 ratio. Thus, the speed of each parallel input line is increased by a factor of two over the general modulation technique described in the basic PLCM.

The shifted modulation signal is coupled to the AC power line 12 by the PLCs 18. As with the basic PLCM all parallel shifted modulation signals are added together into a conglomerate modulation signal and sent over the AC power line to a second PLCM 10a. The second PLCM 10a (not shown) located at another point on the AC power line 12 receives the conglomerate modulation signal and separates and filters each distinct signal at the couplers 18.

Since the PLCs 18 are phase linear due to the use of air-core transformers and impedance matched to the AC power line at the modulation frequency, the encoded phase shifts are

undisturbed when passing through them. Each shifted modulation signal proceeds to the phase lock loop (PLL) circuit 36. The PLL 36 assures the specific predetermined frequency and bandwidth are locked onto and do not drift prior to insertion into the QPSK demodulator 34. A possible bandwidth for the PLL is 50 KHz. Other frequency locking circuits can be used here as well.

At the QPSK demodulator the phase shifts in the modulated signals are demodulated (decoded) back into their original digital form. A 90 degree phase shift is demodulated into a "00" a 180 degree phase shift to a "01", and so forth. The data stream is then sent out on the associated parallel output data line.

Figure 4, similar to Figure 2, depicts how multiplexer and demultiplexer circuits can increase the baud rate of the phase shifting PLCM 10a to that of a high speed data stream input or output line. The multiplexer receives input data on the data stream input line then converts the data to multiplexed parallel data and connects the data to the parallel input lines. The data rate on each input parallel line is equal to the speed of the input data stream divided by the total number of parallel input lines. The more parallel input data lines the greater the speed of the data stream input lines that can be catered to by the PLCM. Using QPSK modulation each parallel input and output parallel data line operates at baud rates of about 160 kbaud. Therefore, if eight input and output data lines are used the overall throughput of the PLCM using quadrature phase shift

keying is 160 Kbaud multiplied by four, totaling 640 Kbaud. The use of more than eight input and output data lines can increase the baud rate dramatically.

If an eight state phase shift modulator (octaphase shift key modulator) (OPSKM) is used instead of a quadrature phase shift modulator (four state modulator) then every three bits of data are assigned to each forty-five degree shift in phase. For example, "000" is assigned a 45 degree phase shift, "001" is assigned a 90 degree phase shift, "010" is assigned 135 degrees, "011" gets 180 degrees, "100 gets 225, "101" gets 270, "110" gets 315, and "111" gets a 360 degree phase shift assigned to it. This technique packs the data in a 3:1 ratio. Thus, the speed of each parallel input line is increased by a factor of 3 over the general input line. Using OPSK modulation and eight parallel input lines, each input line through put will be approximately 80 KSymbols/sec x 4 equaling 320 KSymbols/sec. Multiplying by eight lines the total throughput of a PLCM using OPSK modulation is about 2.5 MSymbols/sec.

The demultiplexer circuitry 26 operates the same way as described for figure 2. The parallel output lines 22, in figure 4, carry the digital data from the QPSK modulators 34 to the multiplexer where it is multiplexed from parallel to data stream data and sent out on the data screen output line 30.

For example, a Digital Signal Processing (DSP) chip can be used, using the ATT DSP 32C in which the digital bandpass filter, the PLL and the OPSK MOD/DEMOD can be programmed. The Carrier

Sense Multiple Access/Collision Detection will be handled in the PLC modem. Logical separation of LAN traffic (addressability) may be used as well as the Forward Error Correction (FEC) and Data Compression, all of which are controlled by the CPU.

Obviously, the best carrier frequencies which can be chosen between the main harmonics of the 60 Hz, are every 30 KHz in the spectrum. In that case, the 1:1 received inband noise (threshold) is only around 5-15 mV peak to peak. Thus, ten channels can be used at the following carrier frequencies: F1=165 KHz, F2=195 KHz, F3=225 KHz, F4=255 KHz, F5=285 KHz, F6=315 KHz, F7=345 KHz, F8=375 KHz, F9=405 KHz, F10=435 KHz using about 20-24 KHz bandwidth for each channel and OPSK. Similarly, about 33.33 KSymbols/sec per channels and 1Mbaud final speed can be reached. The usage of more channels will bring up the price of the modem and since the strong 60Hz harmonics are only every 60 KHz in the spectrum, therefore only four channels are recommended at the following carrier frequencies, while the noise threshold remains about the same as above: F1=210KHz, F2=270 KHz, F3=330 KHz, F4=390 KHz, using about 50-54KHz bandwidth for each channels and OPSK. Similarly, about 83.33 KSymbols/sec per channels and 1 Mbaud final speed can be reached. It is also possible to add a fifth channel at 150KHz. In Europe, the Power Line carrier frequency rules are different. They do not allow higher than 100KHz frequency transmission, therefore four channels are recommended at the following carrier frequencies: F1=56KHz, F2=69KHz, F3=82KHz, F4=95KHz using about 9KHz bandwidth

for each channel and OPSK. The maximum final speed can be about 200Kbaud. Since they have 50Hz power, the strong harmonics appear at every 25KHz in the spectrum, and the threshold is around 15-40mV peak to peak.

Figure 5 and Figure 6 depict examples of how the PLCM and modulator/demodulator circuits can be used in coexistence with network controllers used in a Local Area Network (LAN) system, (Figure 5), or other networking system, (Figure 6). This is an inexpensive technique for creating or expanding a LAN or Ethernet System because no additional wiring must be added to interconnect the system. Other network controllers such as Starlan, Token Ring, etc. can also be used. Also, the use of various types of network software, such as Novell, can be implemented.

Power Line Couplers (PLC's), as described in my co-pending application serial number 822,326 filed Jan. 17, 1992, are part of the present invention's embodiment because of their linear phase shifting qualities. PLC's allow signal information to be placed on conventional electrical wiring and retrieved, noise free, at another position. PLC's allow communication over existing electrical power AC wiring found in buildings. PLC's also allow for communication over long distance through power lines outside buildings. Such a configuration on outside wiring will allow efficient data communication from building to building without the installation of new cabling. With a PLCM, which incorporates a PLC, existing electrical wiring in any form can

become a means for transmitting and receiving communications at rates of speed that can exceed 1 Mbaud.

Figure 7 depicts a possible configuration for data communication between multiple microprocessor based and electrical/electronic equipment. Any personal computer (PC), printer, or other device can be connected to a PLCM 10, 10a. The PLCM, plugged into a standard wall socket, will allow the device to transmit and/or receive communication information over the electrical wiring of the building 12.

Note that if multiple phases are present (phase A, B, & C) and devices which must communicate via a PLCM are connected to separate phases, then a simple circuit 70 can be used to link the phases together.

While particular embodiments of the present invention are disclosed herein, it is not intended to limit the invention to such disclosure, and changes and modifications may be incorporated and embodied within the scope of the following claims.

What is claimed is:

1. A communication apparatus which transmits and receives multiple modulated signals over an electrical line which comprises:

a first station and a second station;

said first station capable of receiving high speed data and converting the high speed data into multiple modulated signals for sending simultaneously over the electrical line to said second station, said second station being capable of simultaneously demodulating the multiple modulated signals and converting the signals back into high speed data; and

each said station incorporating dielectric core couplers for coupling the multiple modulated signals between the electrical line and each station.

2. A communication apparatus in accordance with claim 1 wherein the dielectric-core couplers couple the multiple modulated signals between the electrical line and each station in a phase linear manner.

3. A communication apparatus in accordance with claim 1 wherein the electrical line is any conventional wiring.

4. A communication apparatus in accordance with claim 1 wherein the multiple modulated signal sent over the electrical line can be sent for a distance of 3km.

5. A communication apparatus in accordance with claim 1 wherein the multiple modulating signal is a combination of

multiplexed digital data which is modulated at different distinct preselected frequencies and then combined.

6. A communication apparatus in accordance with claim 1 wherein the high speed data is serial data traveling at a rate of up to 100 KSymbols/sec.

7. A communication apparatus in accordance with claim 1 wherein each station utilizes quadrature phase shift keying techniques when modulating and demodulating the multiple modulated signals.

8. A communication apparatus in accordance with claim 6 wherein the high speed data is serial data traveling at a rate of at least 160 kbits/sec.

9. A communication apparatus in accordance with claim 1 wherein each station utilizes octaphase shift keying techniques.

10. A communication apparatus in accordance with claim 7 wherein the data error rate of the communication apparatus is less than 10^{-9}.

11. A communication apparatus which transmits and receives composite modulated signals over an electrical line at high speeds comprising:

a first station and second station connected to each other by an electrical line;

each station including multiple input and output data lines, modulators, demodulators and air-core couplers;

multiple output data lines carry electrical information to modulators, one data line to each modulator;

said modulators, each operating at a different preselected modulation frequency, modulate output data received from a corresponding output data line and pass such modulated data signal to an air-core coupler;

each air-core coupler, which is phase-shift linear and impedance matched with the electrical line at the preselected modulation frequency, couples each modulated output data signal to the electrical line by creating and output composite signal;

each air-core coupler also receives an input composite from the electrical line and separates the input composite signal into parallel input modulation signals, without effecting the phase of the parallel input modulation signals, and passes said input modulation signals to the demodulators;

each demodulator, one for each input modulator signal, demodulates the input modulation signal and transmits it on an input data line as input data.

12. A communication apparatus in accordance with Claim 11 wherein all input data lines are connected to a multiplexer which multiplexes the electrical information on the input data lines into an input data stream line and

all input data lines are connected to a demultiplexer which demultiplexes the electrical information on the output data stream line onto the output data lines.

13. A communication apparatus in accordance with Claim 12 wherein the input and output data stream lines operate

individually at approximately 80 KSymbols/sec multiplied by the number of input or output data lines.

14. A communication apparatus in accordance with Claim 11 wherein the air-core couplers have a dielectric core.

15. A communication apparatus in accordance with Claim 11 wherein the electrical information on the input and output data lines is analog information.

16. A communication apparatus in accordance with claim 12 wherein demodulators incorporate phase-lock-loop circuitry prior to demodulation.

17. A communication apparatus in accordance with claim 16 wherein modulators and demodulators incorporate Quadrature Phase Shift Keying Circuitry.

18. A communication apparatus in accordance with claim 16 wherein modulators and demodulators incorporate octaphase shift keying circuitry.

19. A communication apparatus in accordance with claim 11 wherein each station includes a multiplexer, demultiplexer, serial input line and serial output line;

each data stream output line carries output data to a multiplexer;

said multiplexer multiplexes the data stream output data onto the multiple output data lines;

each demultiplexer receives input data from the input data lines and demultiplexes the data into data stream input data and sends the input data on the data stream input line.

20. A communication apparatus in accordance with claim 17 wherein both the data stream input and data stream output line travel at data speeds exceeding approximately 1 Mbaud.

21. A method of communication which allows multiple electronic processors to communicate on an electrical line comprising:

providing a first encoder/decoder connected to a first electronic processor and at least a second encoder/decoder unit connected to a second electronic processor, both first and second encoder/decoder units being connected to an electrical line and utilizing air-core couplers;

receiving a first data stream from the first electronic processor;

multiplexing the first data stream into multiple parallel data streams;

modulating each parallel data stream at a different distinct preselected modulation frequency resulting in multiple modulated data streams;

combining the multiple modulated data streams into a combination data stream;

sending the combination data stream on the electrical line in a phase linear manner;

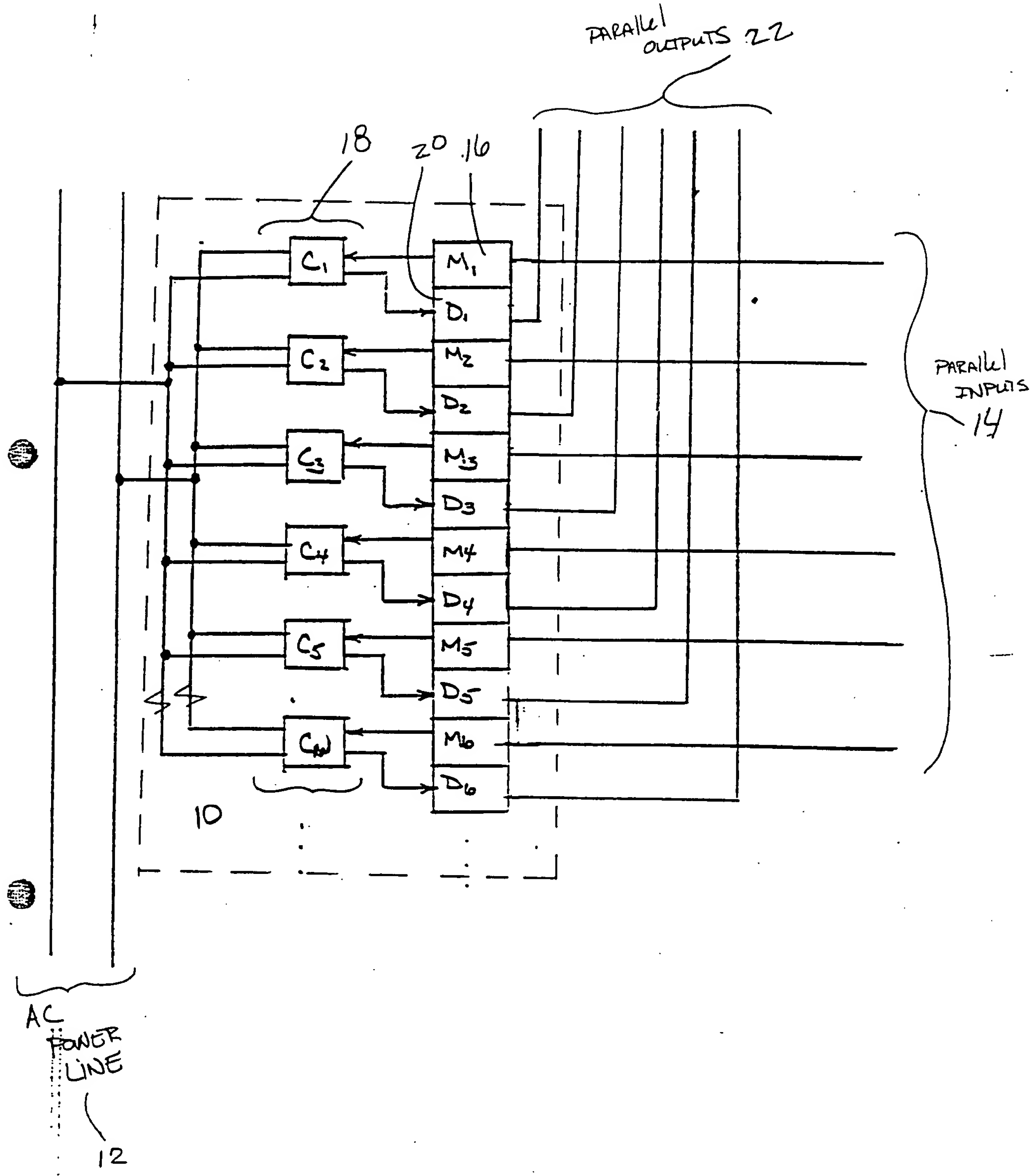
receiving the combination data stream at the second encoder/decoder unit;

separating the combination data stream, in a phase linear manner, into multiple modulated data streams each modulating at a different distinct modulation frequency;

demodulating each modulated data stream and creating parallel data streams;

demultiplexing the parallel data streams into a single second data stream;

connecting second data stream to the second electronic processor.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18
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16
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M_1
D_1
C_2
M_2
D_2
C_3
M_3
D_3
C_4
M_4
D_4
C_5
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D_5
C_N
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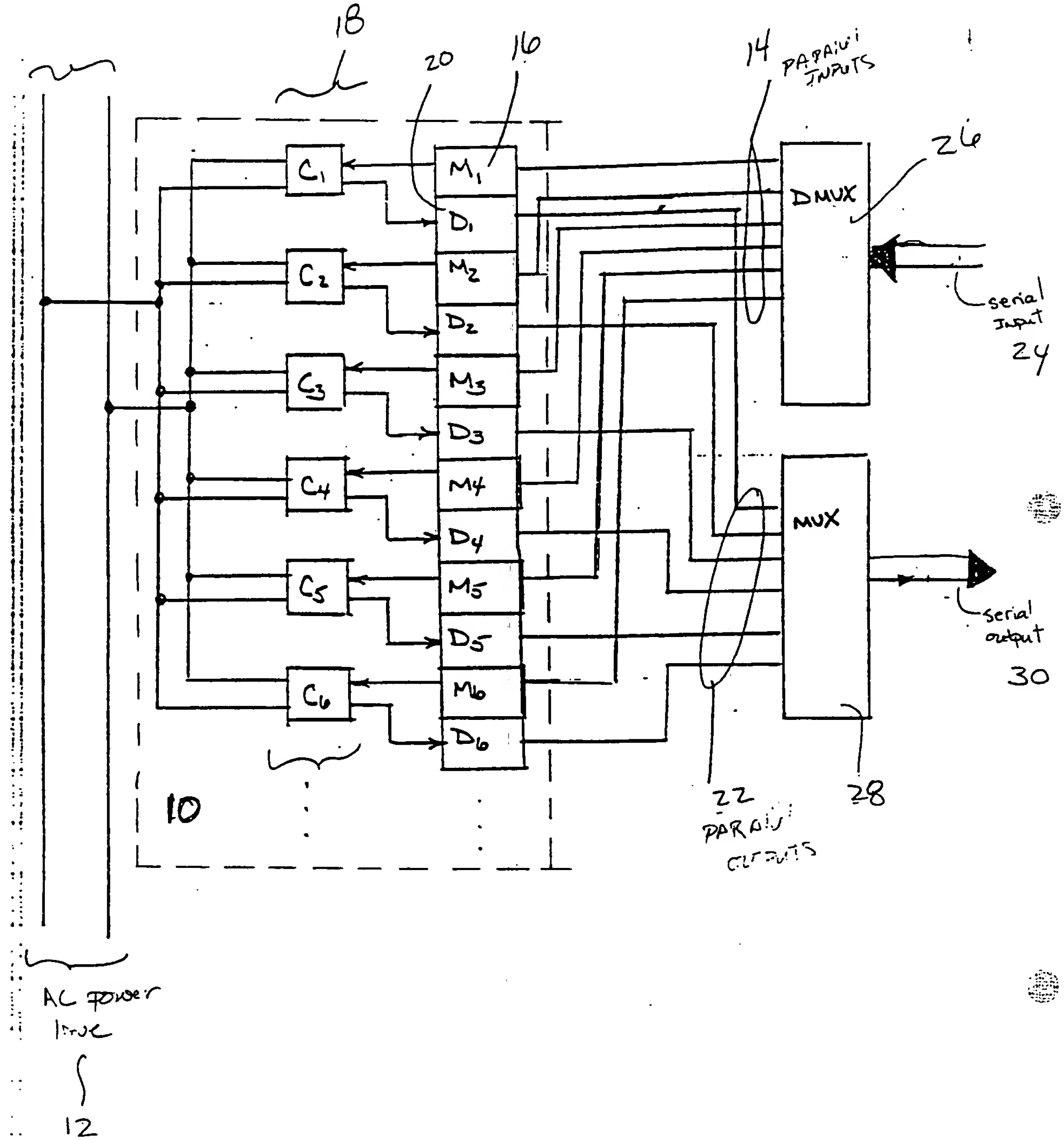
D_6
PARALLEL INPUTS 14
44
10
AC POWER LINE
12

FIG 1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M3
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D4
M5
D5
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PARALLEL OUTPUTS
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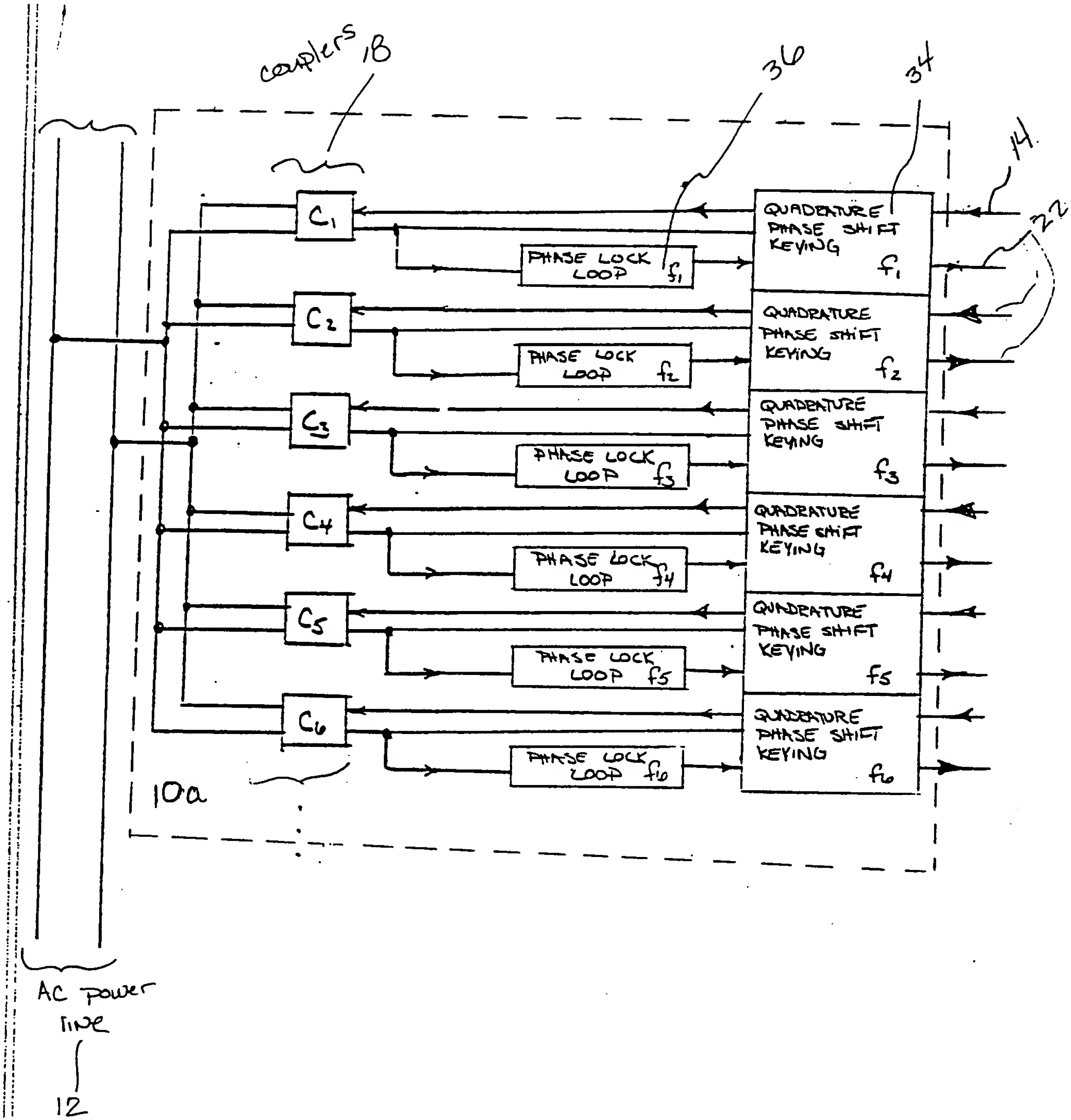
AC power line
12

FIG 2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C3
C4
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PHASE LOCK LOOP f5
PHASE LOCK LOOP f6
QUADRATURE PHASE SHIFT KEYING f1
QUADRATURE PHASE SHIFT KEYING f2
QUADRATURE PHASE SHIFT KEYING f3
QUADRATURE PHASE SHIFT KEYING f4
QUADRATURE PHASE SHIFT KEYING f5
QUADRATURE PHASE SHIFT KEYING f6
10a
AC power line
12

FIG 3

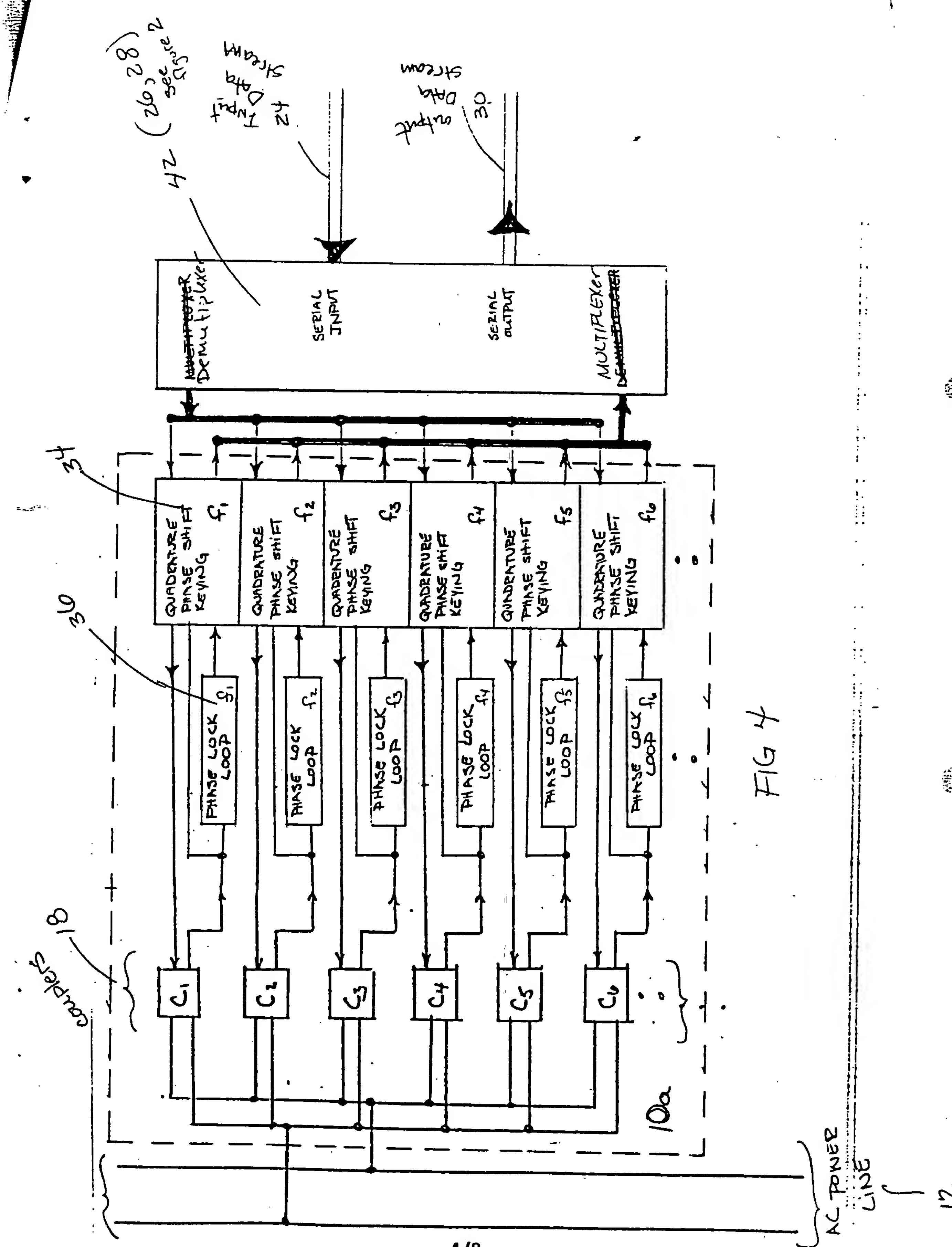
Input Data Stream
24
output Data stream
30
42
(26, 28 see figure 2)
Demultiplexer
SERIAL INPUT
SERIAL OUTPUT
MULTIPLEXER
34
QUADRATURE PHASE SHIFT KEYING f1
QUADRATURE PHASE SHIFT KEYING f2
QUADRATURE PHASE SHIFT KEYING f3
QUADRATURE PHASE SHIFT KEYING f4
QUADRATURE PHASE SHIFT KEYING f5
QUADRATURE PHASE SHIFT KEYING f6
36
PHASE LOCK LOOP f1
PHASE LOCK LOOP f2
PHASE LOCK LOOP f3
PHASE LOCK LOOP f4
PHASE LOCK LOOP f5
PHASE LOCK LOOP f6
couplers 18
C1
C2
C3
C4
C5
C6
10a
AC POWER LINE
12

FIG 4

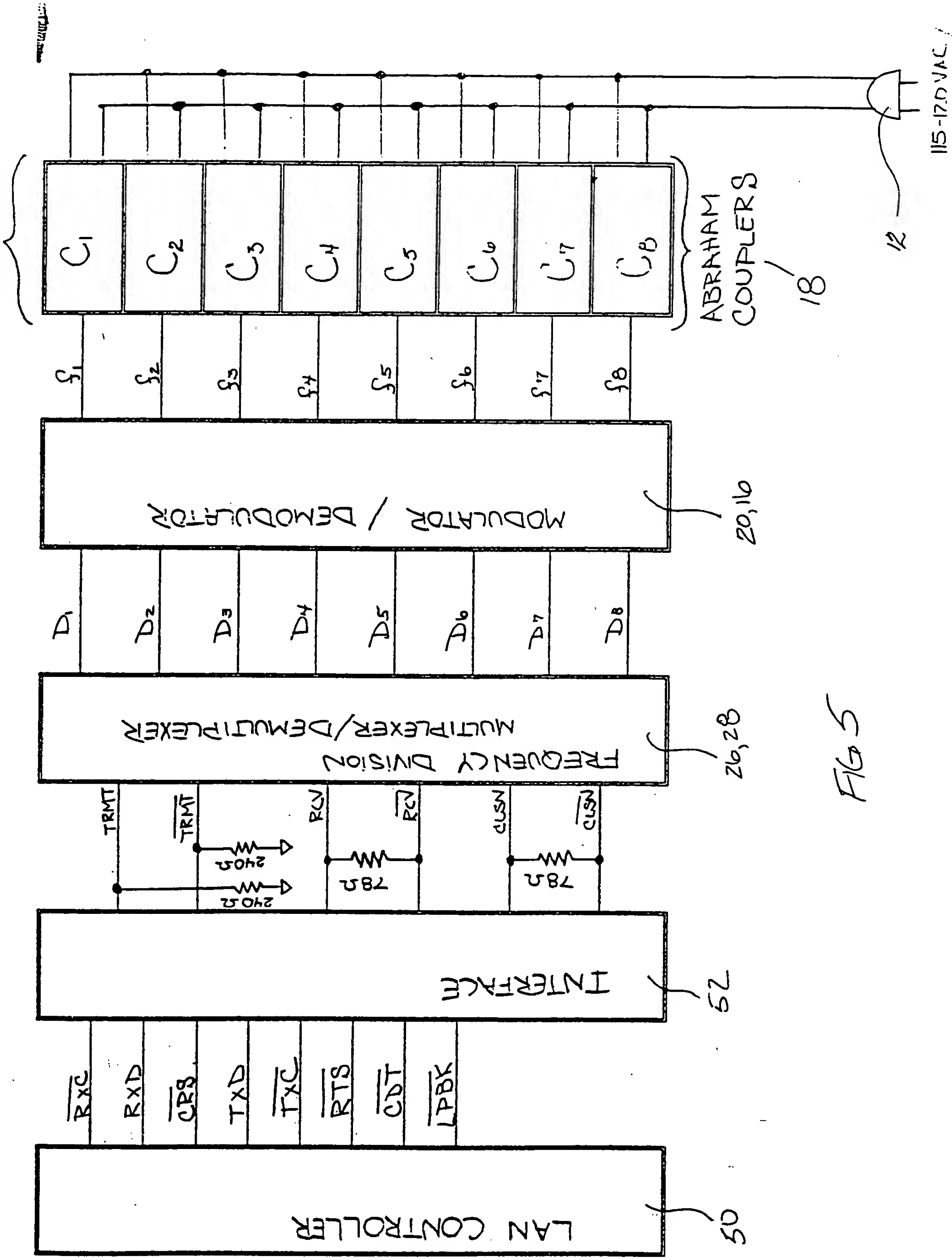
115-120 VAC
12
ABRAHAM COUPLERS
18
C1
C2
C3
C4
C5
C6
C7
C8
f1
f2
f3
f4
f5
f6
f7
f8
MODULATOR / DEMODULATOR
20,16
D1
D2
D3
D4
D5
D6
D7
D8
FREQUENCY DIVISION MULTIPLEXER/DEMULTIPLEXER
26,28
TRMT
TRMT
RCV
RCV
CLSN
CLSN
240Ω
240Ω
78Ω
78Ω
INTERFACE
52
RxC
RXD
CRS
TXD
TxC
RTS
CDT
LPBK
LAN CONTROLLER
50

FIG 5

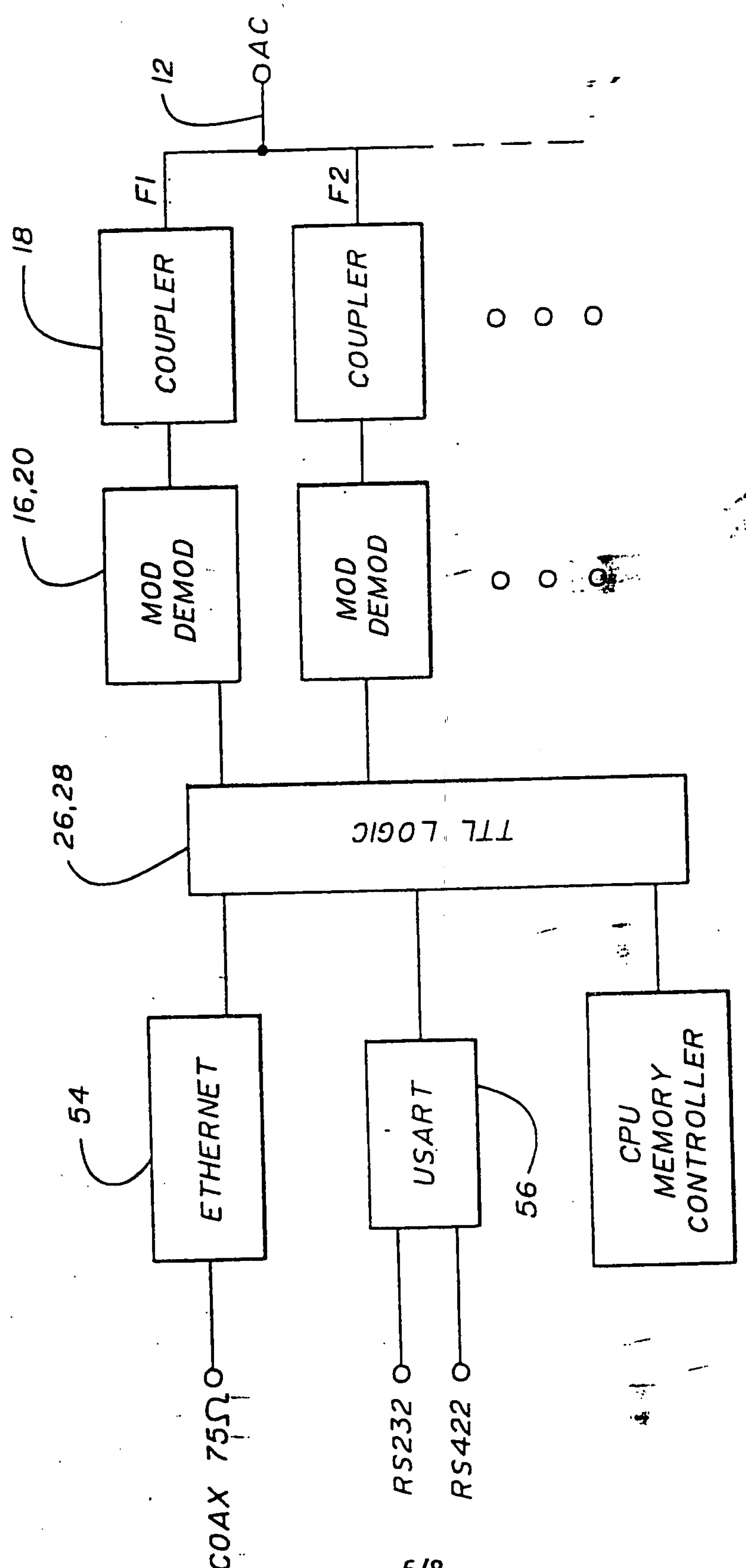
AC
12
F1
F2
18
COUPLER
COUPLER
16,20
MOD
DEMOD
MOD
DEMOD
26,28
TTL LOGIC
54
ETHERNET
USART
56
CPU
MEMORY
CONTROLLER
COAX 75Ω
RS232
RS422

Fig. 6

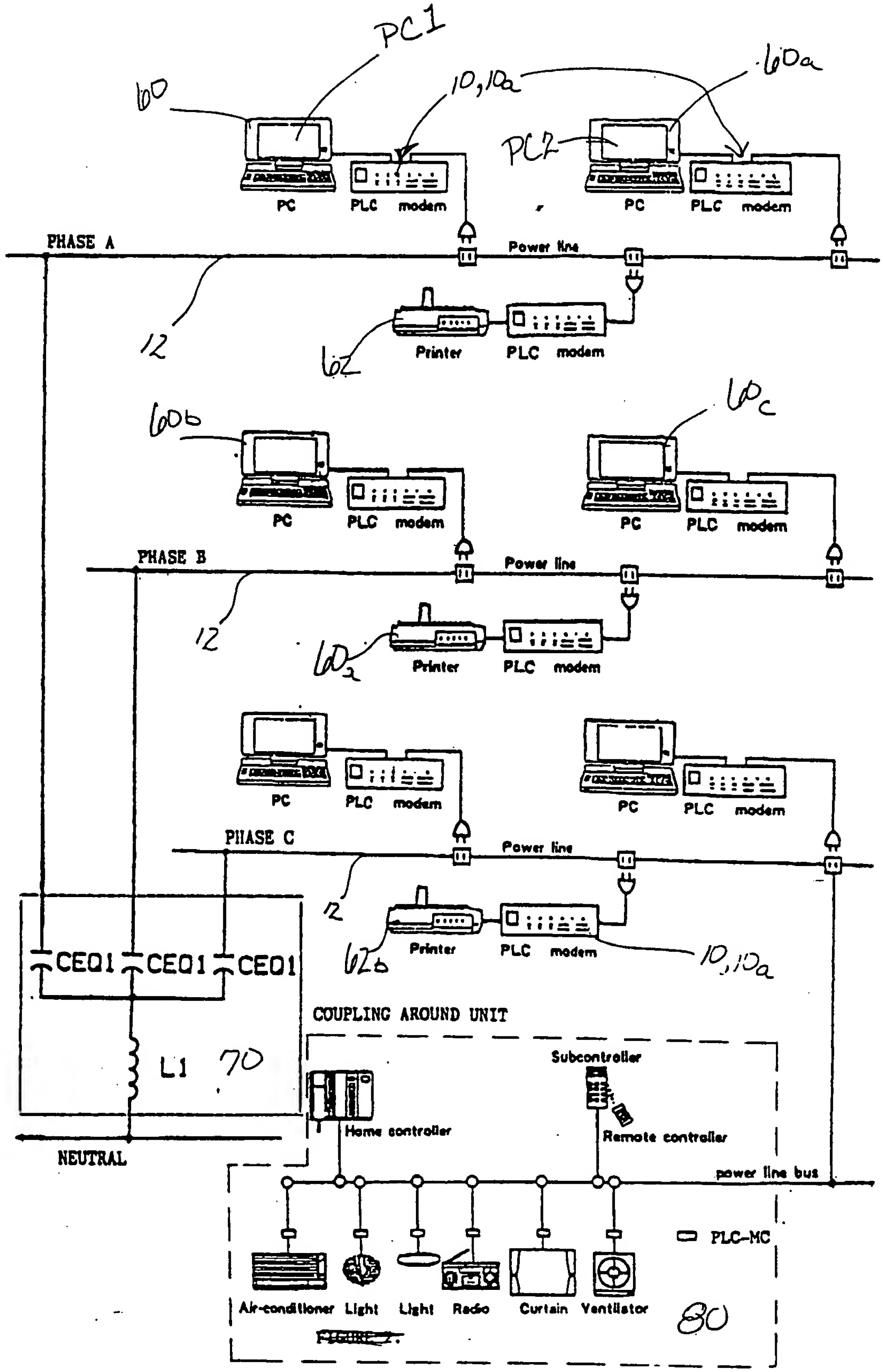
PC1
60
10,10a
60a
PC2
PC
PLC modem
PHASE A
Power line
12
62
Printer
60b
60c
PHASE B
60a
PHASE C
62b
10,10a
CEQ1
CEQ1
CEQ1
L1
70
NEUTRAL
COUPLING AROUND UNIT
Subcontroller
Home controller
Remote controller
power line bus
PLC-MC
Air-conditioner
Light
Light
Radio
Curtain
Ventilator
80
~~FIGURE 2.~~

FIGURE 7

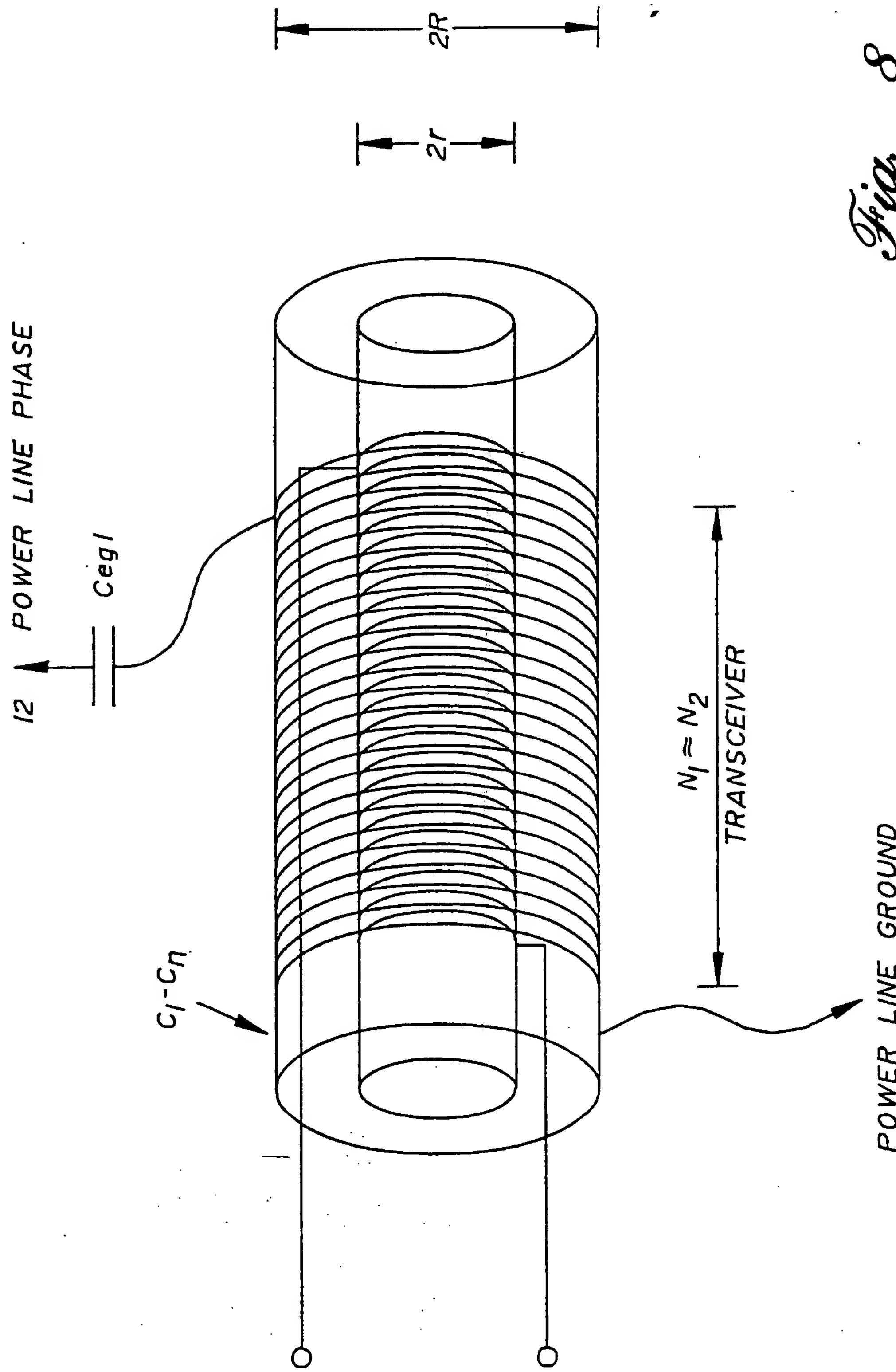

Fig. 8

SUBSTITUTE SHEET

B. FIELDS SEARCHED
Electronic data bases consulted (Name of data base and where practicable terms used):

APS Search: Modem and power line and (phase shift or PSK) Modem (20W) power line.
IEEE/IEE CD system:—Power line and (Modem or phase shift).

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/04726

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :H04B 1/38; H04L 5/16, 27/10; H04M 11/04
US CL :375/8,54,53; 340/310A,310R
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 375/8,54,53; 340/310A,310R; 340/825.58; 375/7,9,52,83,85,37; 455/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A, P	US, A, 5,185,591, (SHUEY) 09 February 1993 see Figure 2 and col. 2 line 45 to col. 2, line 65.	1,11,21
A	US, A, 4,815,106, (PROPP ET AL) 21 March 1989 see col. 5 lines 34-38.	1,11,21
A	US, A, 4,355,303, (PHILLIPS ET AL) 19 October 1982 see col. 1 lines 38-46.	1,11,21
A	IEEE Communications Magazine, May 1990, J.Bingham, "Multicarrier Modulation for Data Transmission: An Idea whose Time Has Come," pages 5-14, see page 5 and Figure 1.	1,11,21

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be part of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 August 1993	27 AUG 1993

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	CURTIS KUNTZ Duane Kobayashi SUPERVISORY PATENT EXAMINER GROUP 2600
Facsimile No. NOT APPLICABLE	Telephone No. (703) 305-4899

wygen ICW. cf
FR 7621599
(pub. 2,326,087)

The present invention relates to a process and a device for transmitting pulses in both directions.

The acquisition of data coming from detection points distributed over extended areas is generating increasing interest. For example, there is a large number of production or finishing stations in the textile industry. In fact, there are weaving mills comprising more than a thousand looms or spinning mills with more than a hundred thousand spindles. These machines are often located in several workshops, distributed over several floors or even several buildings. When such a multiplicity of production points has to be dealt with, it is quite natural to consider monitoring them by means of computers.

However, at the present time, monitoring systems using computers are not very widespread. The main reason for this is probably the high cost as a result of the large number of measurement points to be monitored and their distribution. This high cost does not result solely from the large number of measurement detectors to be provided, but equally, and perhaps above all, from the significance of the system for transmitting data ensuing from it. In fact, in principle, a connection must be established between each production point (referred to hereafter as "transmitter" or "transmission station") and the input section (referred hereafter as "central unit"). Some simplifications may be achieved with multiplexers, but

even in this case a line must be established between the transmitters and the multiplexer. On the other hand, it is often necessary to add such a system on to existing installations. This requires cables and lines to be laid, involving considerable additional expenses.

It is also frequently the case that data has to be sent from the central unit to one of the transmitters, and this requires a bilateral connection. In some cases, this also requires the installation of expensive cable connections.

The present invention avoids all these disadvantages and relates to a process for the bilateral transmission of pulses between a certain number of transmitters generally connected to an electrical distribution network, and a central unit, and it is distinguished in that while they are supplied by the electrical distribution network, both the central unit and the transmitters are coupled to this network at high frequency, and in that this network serves as a bus system for the transmission of data.

The invention also relates to a device for implementing this process, which is distinguished in that it comprises means for high frequency modulation of the pulses to be transmitted, means for inducing modulated pulses in the electrical distribution network, means for extracting these modulated high frequency signals from said network, and means for reconstituting the initial pulses.

The aim of the invention is to interconnect transmitters which are relatively distant from one another to a central unit. The invention uses the electrical distribution network for this purpose. So as to be able to keep these pulses carrying the data and the network voltage separate, these pulses are modulated at high frequency.

The modulation frequencies used advantageously amount to between 50 and 200 kHz. However, they may be higher or lower than these limits. Nevertheless, the indicated frequency range is particularly suitable for transmitting high frequency signals via the electrical distribution network for industrial installations. In fact, for these frequencies the difference in relation to the frequency of the network is large enough without the line impedances being excessive for the transmission of high frequency pulses.

The high frequency signals can be applied between any two phases of the three-phase network. However, it is preferable to apply these between any phase and neutral, safety earth, or, in a very general manner, an earth conductor suitable for high frequency. The latter may, in some cases, be formed by the concrete floor of the building. In this way, the phase shifting capacitors, which are generally connected between the motor phases, are prevented from short-circuiting the high frequency signals. However, it is clearly evident that these phase

shifting capacitors distribute the high frequency voltage virtually uniformly to all phases. This effect may be useful to allow the application and recuperation of high frequency signals to be effected at any phase whatsoever, or in other words, so that the signals can be applied between a certain phase and neutral, and can be recovered between any phase and this neutral.

The application of signals between any phase and neutral, but in such a manner such that in a three-phase network, the high frequency is transferred by the three phases, offers the advantage that the high voltage transformer forms a solid barrier against the outside. In general, the secondary transformer of these high voltage transformers is connected in a star-shaped arrangement, so that no voltage can be transmitted between the three phases and the neutral point. This avoids introducing the pulses into the high voltage network and thus disrupting the operation of other systems for processing information which could be connected thereto. Conversely, this at the same time prevents pulses from being introduced into the low voltage network by the high voltage transformer. In this way, an appreciably restricted field is set up for the data acquisition system which encompasses the entire secondary circuit of the high voltage transformer. This is particularly advantageous in some industrial businesses for the acquisition of data from machines and appliances, since a large number of these businesses have their own high voltage transformer, and therefore the

field of acquisition of data is determined from the outset.

It is clearly evident that in industrial businesses with several high voltage transformers, it is possible to simultaneously set up several data acquisition systems, and that these are linked in the same central unit.

Computer installations often use bus systems which can receive pulses from data acquisition points or can feed them thereto. These bus systems are also linked to an arithmetic element which likewise receives pulses or feeds them to the system. However, in general these bus systems are only assigned to a single appliance or to several appliances housed in the same computer site.

A data processing system comprising a bus network such as that just described generally requires control or clock pulses. Since according to the invention the data acquisition stations and the central unit are already linked to the electrical energy distribution network for the purpose of supply, it is particularly advantageous to use the frequency of the network as clock frequency. In this way, a special device capable of supplying control pulses to the bus system becomes unnecessary.

It is particularly advantageous to adopt a multiple of the frequency of the network as control frequency, in particular a multiple module 3, since any phase conductor

of a three-phase network can thus equally be used for the synchronisation. Therefore, in the case of a triple frequency of the network frequency, or a whole multiple thereof, any phase conductor whatsoever can be used for the synchronisation.

The bus system is generally composed of several line networks. Hence, a first network can receive data from all the transmitters and can feed them to a central unit. A second network could serve to transmit the addresses of the transmitters from the central unit. A third could transmit control pulses, etc. This division of functions is advantageous, since it excludes any risk of confusion between control pulses, address pulses and data pulses.

However, in the present invention there is only one line network, in particular formed by an electrical distribution network. To be able to transmit on different channels, however, several frequencies may be worked with. Hence, data could be transmitted on 100 kHz, for example, and addresses on 130 kHz. However, it is preferable to operate according to a time-division multiplex process, which will be described at a later stage.

It must be noted that the process of the invention and the devices for conducting this process are not restricted with respect to their field of application to the textile industry indicated above as the preferred

field of application. In fact, the invention is also suitable for other businesses and other branches of industry where data have to be transferred in two directions between a large number of stations and a central unit, and where these stations are already linked to an electrical energy distribution network.

Other features and advantages of the invention will be evident form the description below with reference to the attached drawing, wherein:

Figure 1 is a detail diagram of a network to which a specific number of users is connected;

Figure 2 is a pulse diagram for the purpose of better comprehension of the invention;

Figure 3 is a diagram similar to the above; and

Figure 4 is a principle diagram of a three-phase network with transmitters and receivers connected to it.

Figure 1 shows an electrical energy distribution network given the reference 2, which supplies a certain number of machines and appliances, referred to hereafter as "transmitters" 11, 12, 13, ...; 21, 22, 23, ... A central unit 10 is also connected to network 2.

Control or clock pulses are used in the time multiplexer process of data transfer. These pulses must be distributed via a line network to fulfil their function of synchronisation. The present invention provides that synchronisation is assured by the line network supplying the electrical energy, thus rendering a special distribution network for this purpose unnecessary.

The transfer of data proceeds as follows:

The central unit 10 applies a trigger pulse to the network 2. In order to prevent noise pulses from being able to simulate trigger pulses, it is preferable to encode the latter. Figure 2 shows an example of a trigger pulse encoded accordingly. It comprises four moments formed either by one active bit I, or by one inactive bit 0. This trigger pulse is propagated along the network 2 towards connected transmitters 11.., 21.. . These transmitters simply comprise classic counting devices such as ring counters or shift registers, which upon receiving the trigger pulse start to count from a given number, i.e. at the cadence of the frequency of the network or a multiple thereof.

The first transmitter can send its data in the line network as soon as it has received the trigger pulse. These data are preferably not formed by a single pulse, but rather by a series or stream thereof, since each transmitter should generally supply more than one set of

information (Figure 3). In this way, all the desired data may be transferred at the cadence of the frequency of the network or a multiple thereof. As soon as the first transmitter has accomplished the despatch of its data, the second can start emission. The coding device of the second transmitter must be encoded accordingly. Thus, the transmitters are connected in succession to the central unit in order to send their data to it. When encoding the counting devices, care must be taken not to apply the same code to two different stations, since in such a case they would send their data at the same time on network 2 and would also receive them simultaneously therefrom.

During a time interval, e.g. while the transmitter 21 is connected to the network, during which no information is to be transferred, the central unit 10 could apply a drive pulse (or a stream of drive pulses) onto the line network 2. In this case, this drive pulse is only received by the transmitter 21, since the other counting devices have received other codes. Consequently, data may circulate in both directions, i.e. from the central unit towards the transmitters, and vice versa.

Figure 3 shows a stream of pulses destined for station n. In this case, one set of information is sent via the transmitter to the central unit by the network 2 in the first four moments 26. The gating pulse moments 27 are unoccupied and are provided to receive a command through the network 2, if necessary. The following moments of the

interval 28 again serve to transfer data through the station n by means of the network 2. The figure also shows an interval of time 24 assigned to the preceding station n-1, and an interval 29 assigned to the following station n+1.

The time necessary to transfer all the data may be relatively long in a large business. Therefore, it is advantageous not to use the basic frequency of the network but one of its multiples. Moreover, it is particularly advantageous that this multiple is divisible by 3 so that there is no necessity to ensure a good phase line in a three-phase network to assure synchronisation by the electrical network. In fact, with a multiple divisible by 3 of the frequency of the network, any phase conductor whatsoever may be selected for the synchronisation.

Figure 4 shows a schematic diagram of an electrical network comprising three phase conductors L_1, L_2, L_3 and a neutral conductor N. In this example, the transmitter-receiver 20 is connected via a capacitor 19 to the phase conductor L_3 and to the neutral conductor N. The transmitter-receiver 20 is designed in order to transfer data in the form of coded pulses and to receive commands in the same form converting them into switching signals. In the same diagram, in addition to the production and transmission of control pulses, the central unit 10 is constructed in order to transform data coming from the

transmitters into corresponding data, to save these and, if necessary, display them, and also to be able to convert commands destined for the transmitters into suitably coded pulses and send them onto the network 2.

It is clearly evident that other methods of coupling between the transmitter-receiver 20 and the network 19 may equally be used, for example, a series inductance coupling, whereby the signals may advantageously be applied between an actual or artificial neutral of the three-phase network and the neutral line or safety earth, or even a suitable high frequency service earth.

Patent Claims:

1. Process for the bilateral transmission of pulses between a certain number of transmitters generally connected to an electrical distribution network, and a central unit, characterised in that while they are supplied by the electrical distribution network, both the central unit 10 and the transmitters 11, 12, 13; 21, 22, 23 are coupled to this network at high frequency, and that this network serves as a bus system for the transmission of data.

2. Process according to Claim 1, characterised in that in the case of a three-phase electrical distribution network, the high frequency signals are applied between at least one phase conductor, on the one hand, and the neutral conductor or a safety neutral, or even a suitable service earth with respect to the high frequency, on the other hand.

3. Process according to Claim 1, characterised in that a time-division multiplex process is used to transfer data.

4. Process according to one of Claims 1 and 3, characterised in that at least one specific trigger signal is applied to a line network 2 of an electrical energy distribution network, and this trigger signal sets in operation a counting device

in each transmitter 11, 12, 13 of control pulses coming from the network frequency to assure the advance of said counting devices, and that each counting device is coded to a determined number of control pulses subsequent to the trigger pulse, and that, upon arriving at this number of control pulses, during an interval of time 25, data are applied to the line networks 2 or are received by this.

5. Process according to one of Claims 1 and 3, characterised in that the trigger pulse is encoded for the time-division multiplex process.

6. Process according to Claim 1, characterised in that because of different codes, several data acquisition systems are supplied by the same electrical distribution network.

7. Process according to Claim 1, characterised in that the time interval 25 corresponds to the duration of a control pulse.

8. Process according to Claim 1, characterised in that the time interval 25 corresponds to the duration of two or more control pulses.

9. Process according to Claim 1, characterised in that the frequency of the modulated high frequency

signals amounts to between 50 and 200 kHz.

10. Process according to Claim 1, characterised in that the frequency of the control pulses is determined by that of the network.

11. Process according to Claim 1, characterised in that the frequency of the control pulses is a multiple of that of the network.

12. Process according to one of Claims 1 and 11, characterised in that in a three-phase electrical distribution network, a multiple of the network frequency which is divisible by three is adopted.

13. Device for implementing the process according to any one of Claims 1 to 12, characterised in that it comprises means for high frequency modulation of the pulses to be transmitted, means for inducing modulated pulses in the electrical distribution network, means for extracting these modulated high frequency signals from said network, and means for reconstituting the initial pulses.

14. Device according to Claim 13, characterised in that it comprises a central unit 10 which supplies trigger pulses to the line network 2 ensuring the supply of electrical energy, and also counting devices in each transmitter 11, 12, 13, ... which

are controlled by said trigger pulses and which advance under the action of control pulses coming from the network frequency, said counting devices being coded to predetermined numbers of pulses and, when this number is reached, being capable of supplying or receiving data during a given time interval 25.

15. Device according to one of Claims 13 and 14, characterised in that the central unit 10 is designed to receive data from the transmitter 11, 12, 13, ... which has been set in operation during the time interval 25, or to send it commands during this time.

16. Device according to Claim 13, characterised in that a transmitter-receiver 20 connected to the line network 18 emits or receives modulated high frequency pulses during the time interval 25.

17. Device according to one of Claims 13 and 16, characterised in that the transmitter-receiver 20 is connected to the line network 18 via a capacitive coupling.

18. Device according to one of Claims 13 and 16, characterised in that the transmitter-receiver 20 is connected to the line network 18 via an inductance coupling.